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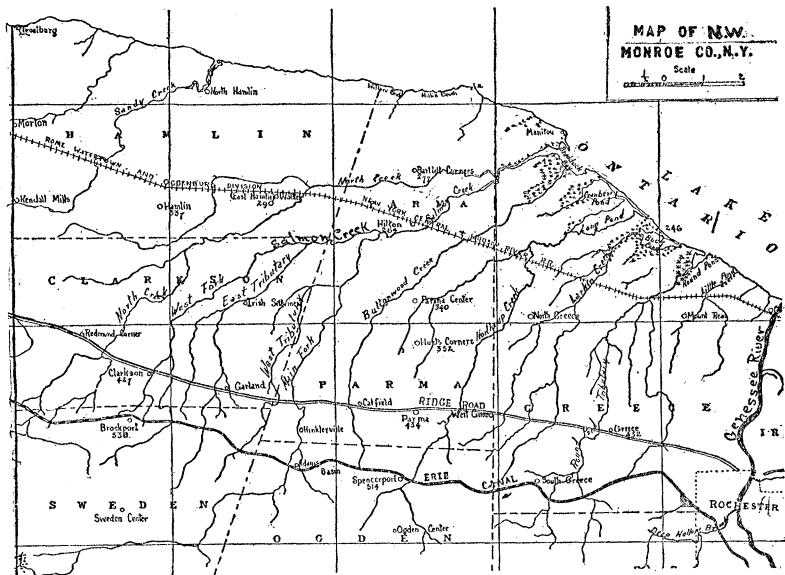
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FISH SUCCESSION IN SOME LAKE ONTARIO TRIBUTARIES

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IN the summer of 1904 the writer spent the whole season in surveying ten streams of Monroe County, New York, and in plotting the range of each species of fish in them according to a plan outlined in 1907.¹ The following year, 1908, tentative



MAP NO. 1.

conclusions were formulated and conditions in Cayuga Lake streams contrasted with those of Monroe County. In 1912 cursory work in Ontario province caused a revision of this draft.

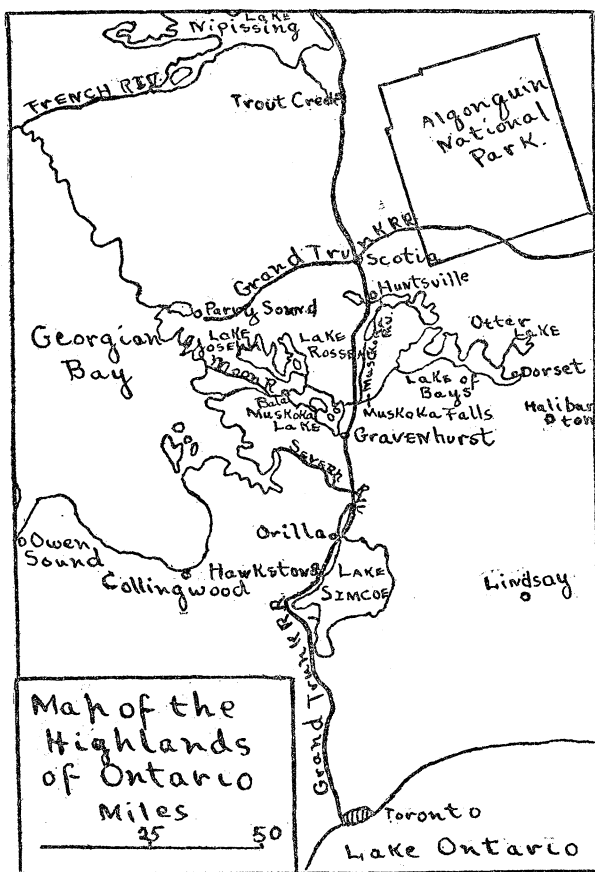
In 1911 an independent study of the same sort was made by Dr. V. E. Shelford,² in the vicinity of Chicago and our studies are in general in agreement.

These ten Monroe streams (Map 1) to which I have alluded are quite ideal for the study of fish succession because they are

¹ *The American Naturalist*, Vol. 41, June, 1907, No. 486, pp. 351-354.

² "Ecological Succession. I. Stream Fishes and the Method of Physiographic Analysis," *Biol. Bull.*, Vol. XXI., No. 1, June, 1911, pp. 9-35.

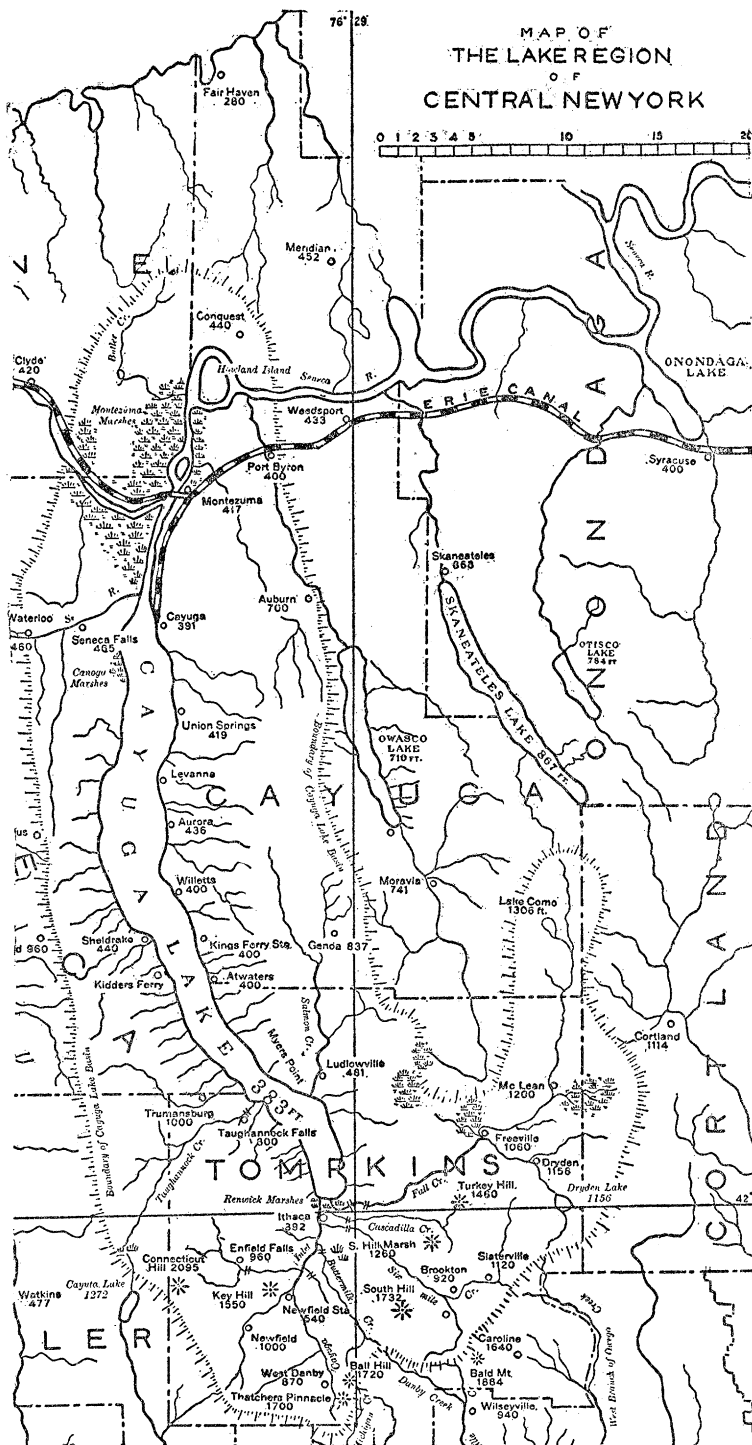
in the old bed of Lake Iroquois and have come into being since its beach (Ridge Road on map) retreated to the present shore of Lake Ontario. They are then postglacial in origin and comparatively recent. For comparison, we have employed Meek's



MAP No. 2.

results in the highlands of Ontario³ (Map 2). He began at Hawkstone and Orillia on Lake Simcoe and followed the Grand Trunk railroad to Trout Creek (Lake Nipissing) or farther north. All the way northward this railroad bears away from Georgian Bay and the stations he successively came to were successively farther away from it in barriers, etc. Added to his results are the experiences of the writer from The Lake of Bays to Fletcher Lakes below Algonquin National Park. The northern end of Cayuga Lake (Map 3) is more comparable to

³ Field Columbian Mus. Zool. Ser., Vols. I., No. 17; III., No. 7.



MAP NO. 3.

Monroe streams and its fish inhabitants bear out the contention. Many forms are common to the two but absent at the south end of Cayuga Lake. The upper reaches of the streams at Ithaca where barriers exist near the lake are more comparable to Otter Lake or Trout Creek of Ontario. Added to the results are the comparisons from some of the Susquehanna head streams, 8-12 miles south of Ithaca. These tributaries are, however, of another drainage system and may not be so pertinent to this discussion.

In a diminutive rivulet or a developing small creek where the current is moderate and the bottom clayey, gravelly or varied the first occupants are almost sure to be the sucker (*Catostomus commersonii*), the horned dace (*Semotilus atromaculatus*) and quite likely the black-nosed dace (*Rhinichthys atronasus*). The second seems to be the original and oldest carnivore of a typical eastern stream in its first development. Thus, in central New York, in most of the hanging valleys which empty into the Finger Lakes, suckers, horned dace and black-nosed dace are about the only original occupants above the high falls and toward the sources unless the brook trout (*Salvelinus fontinalis*) be present. In our ten Monroe streams we did not record the red-bellied minnow (*Chrosomus erythrogaster*), but Evermann and Kendall took it in Salt Brook, a small creek of Webster, and in Long Pond. In many streams and lakes of the province of Ontario it is one of the first to enter and might follow close after the above three species. This may explain its presence in the Cayuga Lake Basin only in the headwaters of Fall Creek where barriers intervene between its habitat and Cayuga Lake. Another form which was taken in a little side stream of the West Fork of Salmon Creek is the fathead minnow (*Pimephales promelas*). At Ithaca, the sole record for it is in the upper waters of one of our oldest streams, namely, Fall Creek (Meek, 1889) and above the barriers near Cayuga Lake; in some of the most inaccessible lakes (Great Lakes' drainage) of Ontario it is present as it is in the headwaters of the Susquehanna. In some streams or headwaters a representative of a very pretty group of minnows may possibly be associated with the last two species. It is either the red-sided minnow (*Leuciscus elongatus*) or Cope's minnow (*Leuciscus neogæus*). In the headwaters of the Susquehanna, the former is very abundant, and Evermann and Kendall had it from several small streams at the east end of Lake Ontario, while the latter form (*L. neogæus*) occurs in some of the highland lakelets of Ontario. In the Monroe County tributaries of Lake On-

tario, two minnows are amongst the species to follow after the original three as given above. These forms are the blunt-nosed minnow (*Pimephales notatus*) and the common shiner (*Notropis cornutus*). In the beginning, therefore, our small streams have in fish content a decidedly soft-rayed element. As the stream develops in width, length and diversity these forms either become our most adaptable forms and range throughout the length of the stream or betake themselves to the source or else succumb and therefore in a measure falsify the present record of fish succession.

The next incomers are usually the first of the spiny-rayed fish and are amongst the most diminutive, namely, the brook stickleback (*Eucalia inconstans*) and the fan-tailed darter (*Catnotus flabellare*). In some waters it would seem that almost concomitant with these comes the miller's thumb (*Cottus richardsoni*). Of this we are not so positive. In the smaller streams the stickleback is usually near the source and the darter may be at the source in mid-course or near the mouth. They are present, however, in almost every one of the Monroe County streams, irrespective of subsequent developments of the lower course, whether deep, muddy and marshy or swift, broad and gravelly. Following close on the heels of these spiny-rays comes the river chub (*Hybopsis kentuckiensis*) which we have recorded in all of our ten streams (small to large streams) and usually sparingly in mid-course or near the mouth. Another form which invades the new stream at about the same stage as the river chub is the stone-roller minnow (*Campostoma anomalum*), an upper course form if the lower course becomes muddy or a lower course form as well if the bottom becomes gravelly rocky or diversified. At this stage our hypothetical stream in its fish inhabitants virtually has its duplicate in Larkin Creek. Or this distribution of fish forms (river chub and stone-roller minnow not represented) is beautifully illustrated in the headwaters of Cayuga Lake Inlet. This stream is the only stream near Ithaca without obstructions or decided glaciated barriers.

The second carnivore and depredator of any size to enter is the pike (*Esox lucius*), closely associated with its smaller relative, the grass pike (*E. vermiculatus*). The former occurs in all ten Monroe streams, and it alone appears in Larkin Creek, while the grass pike occurs in seven streams. Where both are recorded the pike's range is usually greater, and it remains the longest in the oldest portions of a growing stream. This is illustrated in the Salmon Creek and in West Fork of Salmon

Creek, two stretches of the oldest stream courses under consideration. Here the pike alone remains, but in the more recent tributaries of each of these older streams both pike and grass pike occur and the former with the greater range.

About the time of the ingress of the pike, the lower course may possibly begin to deepen, the current become slower and the bottom muddy. Amongst the very first forms to appear along with such conditions is the common bullhead (*Ameiurus nebulosus*). This form is the most widespread in its distribution and most versatile in its adaptation of any of the three species of *Ameiurus* we have. Following the bullhead comes the first Centrarch, the common sunfish (*Eupomotis gibbosus*).

At this juncture our fish content compares favorably with the inhabitants of the upper reaches of Fall Creek Cayuga Lake) above the falls. The forms are: sucker, horned dace, black-nosed dace, fallfish (*Semotilus corporalis*), red-bellied minnow, fathead minnow, brook stickleback, miller's thumb, brook trout, pike, reticulated pickerel (*Esox reticulatus*), bullhead, and sunfish. Or Otter Lake above Lake of Bays (Ontario) may be comparable with its sucker, horned dace, red-bellied dace, fathead, Cope's minnow, blunthead, shiner, brook trout, bullhead, sunfish. Or Trout Creek, a small tributary of Lake Nipissing, may represent the same point with the following forms: sucker, horned dace, red-bellied dace, fathead minnow, blunthead, shiner, brook trout, brook stickleback, and sunfish. Or the very headwaters of the Susquehanna, nearest Ithaca, have a very similar fish fauna, to wit, sucker, horned dace, black-nosed dace, shiner, fathead, red-sided minnow, brook trout, miller's thumb, pike, pickerel, bullhead, and sunfish.

The golden shiner (*Abramis crysoleucas*) appears in quantity after the sunfish and is followed by a few perch (*Perca flavescens*) and the rock bass (*Ambloplites rupestris*). This summation or analysis of our ten streams has brought us unwittingly to the second youngest stream of the ten Monroe tributaries, namely, the West Tributary of the Main Fork of Salmon Creek. This tributary has only the forms recounted to this point.

The large-mouth black bass leads the way in the next associated group and occurs in eight of the ten Monroe streams. In four of the five main systems the black bullhead (*Ameiurus melas*) frequents the lower three or four miles of the stream. A close companion of the black bullhead is the tadpole cat (*Schilbeodes gyrimus*) which is recorded in five of the ten

Monroe streams and the mud minnow (*Umbra limi*) has much the same range and time of entrance. These four forms are almost synchronous in migration into the stream or the above order of the four may possibly show the succession. The first has, if anything, a longer range in the Monroe streams than the second, the second more than the third and the third more than the fourth if both occur in the same stream. We have now reached the third stage in our Monroe water courses, the state of affairs in the East Tributary of the West Fork of Salmon Creek. About this same period the Johnny darter (*Boleosoma nigrum olmstedii*) appears. It occurs in six of our streams or in five different systems, toward the gravelly, stony or clayey sources of two streams with muddy lower courses or in the mid-course of the other four more gravelly streams. In some streams the common killifish (*Fundulus diaphanus*) may enter soon after the previous forms or be associated with them. This development brings the succession to Round Pond Tributary.

A form which comes into consideration at this point is the chub sucker (*Erimyzon sucetta oblongus*). It was scarce in the West Tributary of Northrup Creek, rare in the lower part of Salmon Creek, and quite regular in the lower eight miles of North Creek, our most advanced muddy stream. Disregarding the lone bluegill (*Lepomis pallidus*) record, the West Tributary of Northrup Creek represents this stage. A common minnow (preferring a muddy sluggish course) enters. It is the Cayuga minnow (*Notropis cayuga*) and appears in the lower four miles of Buttonwood and North Creeks. The bowfin (*Amiatus calvus*) is associated with the three bullheads (*Ameiurus nebulosus*, *A. melas*, and *A. natalis*) in the lower part of two of the muddiest streams and occurs sparingly at the mouth of Salmon Creek. Requiring about the same conditions, the yellow cat (*Ameiurus natalis*) appears in a similar range. In one creek at one point we have the progress carried farther with the introduction of the pirate perch (*Aphredoderus saynnus*). This leaves us at the Buttonwood Creek stage. The pirate perch appeared more frequently in the more advanced muddy creek, namely, North Creek, and the succession in this stream goes even farther to the introduction of the mud darter (*Boleithys fusiformis*). Upon the entrance of the small-mouth black bass (*Micropterus dolomieu*) at the mouth of North Creek on a few stony stretches we close this stream's development.

Thus we have from the beginning of muddy conditions the successive appearances of the common bullhead, common sunfish, golden shiner, perch, rock bass, large-mouth black bass,

black bullhead, tadpole cat, mud minnow, Johnny darter, common killifish, chub sucker, Cayuga minnow, bowfin, yellow cat, pirate perch, mud darter, and small-mouth black bass.

As the stream widens its valley, cuts back into the country, these forms push up to favorable habitats above or remain at the mouth or with increasing age of the stream may enter a tributary to recapitulate the succession beyond the first forms. For example, at Ithaca we have the Monroe succession being enacted in Fall Creek. It is naturally a wide, swift, gravelly stream from source almost to the mouth, and there are no decided muddy intervals except as produced by artificial mill dams. From its source to Cornell University campus (20 miles or more) we have most of the fish associates from the sucker to the common sunfish. Through the campus comes a deep rocky ravine with a series of high falls, the last one (Ithaca Falls) being only a short distance from Cayuga Lake. The run from the Ithaca Falls to the lake is short and takes the water mass of the upper 20 miles or more. As a consequence it is gravelly or stony, very swift and very short. There are, therefore, from source to Cornell University campus no attainable muddy stretches, because the postglacial falls bar entrance to the muddy associates of the mouth. Near the mouth of Fall Creek is a small tributary or bayou, deep and muddy, and in it we have the following: common bullhead, common sunfish, golden shiner, perch, rock bass, large-mouth black bass, Johnny darter, tadpole cat, common killifish, Cayuga minnow, in abundance according to the order of the list, *i. e.*, the first three being the most common. Just outside, and slightly above the mouth of this bayou, is the swift water of Fall Creek, where the small-mouthed black bass is the most frequent large fish present. Then follows the succession of the swift gravelly or sandy group to be discussed later. Thus, we have in the source of Fall Creek the first comers to the stream; then, the second muddy group can not follow after them because of falls, but rather go off into a side-stream near the mouth or remain in the mouth; over the backs of the muddy associates or past the mouth of the new home of these enters sparingly the third assemblage, to occupy only the one eighth of a mile stretch of gravelly or sandy bottom below Ithaca Falls. As a consequence, the succession is not carried as far as in the long well-developed lower course of Salmon Creek. The mouth of the West Fork of Salmon Creek in its fish content is about intermediate between the lower courses of Fall and Salmon creeks.

Some might feel that the Johnny darter should be thought

of as entering the succession after or near the small-mouthed bass, but this darter is not restricted to a gravelly bottom and swift current as many of the other darters are. Hence, its place with the previous forms. In the mouth or lower course of the West Fork of Salmon Creek we have left unmentioned in the succession silver-sided minnow (*Notropis atherinoides*), log perch (*Percina caprodes zebra*), spot-tailed minnow (*Notropis hudsonius*), and hog-nosed sucker (*Hypentelium nigricans*). Another place quite comparable is Lake Simcoe or Moon River just below Muskoka Lake (Bala). In the former Meek secured the silver-sided minnow, log perch, spot-tailed minnow, silvery minnow (*Hybognathus muchalis*), trout perch (*Percopsis omiscomaycus*), and long-nosed dace (*Rhinichthys cataractæ*); in the latter locality he secured log perch, spot-tail minnow, and silvery minnow. In the lower course of Fall Creek we have the silver-sided minnow, log perch, silvery minnow, spot-tail minnow, trout perch, satin-fin minnow (*Notropis whipplii*) and eel (*Anguilla rostrata*). In the spring the lampreys (*Petromyzon marinus unicolor*) and the calico bass (*Pomoxis sparoides*) and a stray gar (*Lepisosteus osseus*) may enter it. In Salmon Creek the succession has gone much farther. Besides the forms of Fall Creek we have in Salmon Creek the following: hog-nosed sucker, stone cat (*Noturus flavus*), green-sided darter (*Etheostoma blennoides*), straw-colored minnow (*Notropis blennioides*), and the barred mad-tom (*Schilbeodes miurus*). Not infrequently a mullet (*Moxostoma aureolum*) or a bluegill may just enter the lower reaches of the stream. Rarely a sheepshead (*Aplodinotus grunniens*) or wall-eyed pike (*Stizostedion vitreum*) wanders into the mouth. Just at present the latest arrival in the lower reaches of the Salmon Creek seems to be the marine two-spined stickleback (*Gasterosteus bispinosus*). The forms above are the newest species of an older stream whose course becomes more diversified in general or at its mouth more like the Great Lake conditions. Some of the fish of this last group are as much lake species as stream inhabitants and some almost entirely lake forms. Salmon Creek has a much broader valley and longer course than any other of the Monroe watercourses previously considered and therefore has the succession farthest advanced.

The value of such an analysis as the above may not be apparent at once and may seem too speculative. But, if one considers a stream's drainage system, its size, and its geological history, he ought to be able to approximate its hypothetical fish content. Such studies may be an auxiliary in physiographic

work, *e. g.*, the writer when surveying Salmon Creek (not of Monroe County) of Cayuga Lake drainage discovered fantailed darters near its source and at once concluded there were no natural barriers in it from the lake to its source and the conjecture was right. Or it may be that the peculiar source inhabitants of some large creeks of glaciated areas may indicate that the upper half was connected with another drainage than the present one and a comparison of fish species may help to confirm such a contention. Often one may be at a loss to explain a certain species at the source of a creek and later find that it came across a divide from another drainage system and about Ithaca we have more than one instance of two sources being on the same level and continuous at floodtime.

One important recent factor in falsifying the record of fish succession is the rôle of our canals. The Erie Canal may be responsible for the several forms which occur at the northern end of Cayuga Lake, which make its fish population more like that of Lake Ontario or Lake Erie than like its own southern end. The most recent Erie contribution in the mouths of our Ithaca streams is the gizzard shad (*Dorosoma cepedianum*) and fifteen years ago or more one or more Monroe streams had in their upper courses, carp, eel, perch and spot-tail minnow contributed by the Erie Canal.